



Tree Growth Yield and Fruit Quality of Different Apple Cultivars Trained as Super Spindle

Emine Kucuker^{1*}, Kenan Yildiz¹, Yakup Ozkan²

¹Department of Horticulture, Faculty of Agriculture, University of Gaziosmanpasa, 60240 Tasliciftlik, Tokat, Turkey; ²Department of Horticulture, Faculty of Agriculture, University of Süleyman Demirel, Isparta, Turkey. *Corresponding author email address: emine2346@gmail.com

Received : November 25, 2014

Accepted : February 18, 2015

Online : March 14, 2015

Abstract - This study was carried out on Topaz, Cooper 39 and Muscat apple cultivars grafted on M27 rootstocks under Tokat ecological conditions during 2008 - 2010. The trees planted in 2.0 m x 0.5 m row spacing (10,000 trees ha⁻¹) and trained to super spindle (SS) training system. The vegetative development, yield and fruit quality performances of the trees supported by wire – pole combination were observed for three years. At the end of the experiment, it was determined that Cooper 39 had a higher trunk cross sectional area (TCA) than Topaz and Muscat. While cumulative yield (CY) per tree and cumulative yield efficiency (CYE) were determined to be the highest in Cooper 39, these values were found to be the lowest in Topaz. CY per hectare over the first three crop year was found to be the highest in Cooper 39 and the yield reached to 142.9 t.ha⁻¹. The lowest CY per hectare (69.6 ton ha⁻¹) was determined in Topaz.

Key words: Apple; Super spindle system; Fruit quality; Yield efficiency

Introduction

Although apple is grown over several regions with temperate climates throughout the world, commercial production activities are common over the regions or countries with strong competitive power (Dumanoglu *et al.*, 2009). Apple production of Turkey is increasing with each passing day. However, low unit area yields and lack of cultivars with strong competitive power in foreign markets negatively affect the exports (Özkan *et al.*, 2009). Apple production in Turkey has a very long history and cultivars grafted over seedling rootstocks have recently be used in production activities. However, in orchards established with such rootstocks, number of trees per unit area is very low, cultural practices are difficult, trees start to yield late and full yields are reached about 10-12 years (Küçük *et al.*, 2014).

High density planting systems allow early harvest with high efficiency and high quality fruit production, and they return the investment costs earlier. Early production also provides an opportunity for the growers of new cultivars to benefit from a higher price advantage (Barritt, 1992). For this reason, high density planting has been highly favored by European and American growers for the last 30 years (Wertheim *et al.*, 2001; Hampson *et al.*, 2002b). High density planting systems are already being implemented by some growers in Turkey and they have spread to larger areas in recent years (Özkan, 2008).

The pruning and training principle in modern fruit growing is the most important factor in areas where high yield is targeted, and it directly affects to produce fruit early in the life of the orchard and high fruit quality expected from an orchard.

Early harvest is maintained with the selection of appropriate training technique and by ensuring the constant development of branches in horizontal position and encouraging generative development by weakening the shoot development with the least pruning (Heinicke, 1975; Barritt, 1992; Baugher *et al.*, 1994; Hampson *et al.*, 2002a; Marini and Barden, 2004). Tree height and the form of cover affect the entry and distribution of light into canopy, therefore the training

systems allowing better branch angles provide better light distribution and efficiency (Hampson *et al.*, 2002a; Hampson *et al.*, 2004). Indeed, several researchers emphasized that tall trees collected more light than short trees and that they were more efficient (Hampson *et al.*, 2002b).

Super spindle is among the most commonly used training systems worldwide in dwarf orchards. The aims in super spindle system are early harvest, high yield, less chemical application, less manual labor and lower labor costs. The basic objective of the present study was to investigate the potential use of this world-wide common system in Turkish orchards and find of the effects of training system on yield and quality parameters of apple orchards.

Materials and Methods

Planting and training description

Non-feathered forty five trees of Cooper 39, Topaz and Muscat apples on M27 rootstock were planted in north-south rows in December 2006, into a light sandy loam soil that was used for about 20 years to grow field crop. As a precaution against crown gall, Nogall® (20 g.l⁻¹) was applied to root before planting. Trees were planted with the bud union 10 cm above the soil line. After planting, trees were watered by hand. One week after planting drip irrigation was installed. Trellis installation was completed before the planting.

Tree spacing was 2.0 x 0.5 m for super spindle (10 000 trees.ha⁻¹). Super spindle trees were developed without pruning of tree at planting, and the leader was not headed until year 4. acutely angled shoots that more than half the diameter of the central leader were removed. In leaf 3, two old branches with weak annual shoots were cut back to promote shoot strength. Water sprouts were removed through ripping. In leaf 4, fruiting wood replacement continued and tree height was limited by one single cut into two year old generative wood (Weber, 2001; Robinson, 2007).

The experiment was laid out in a randomized complete-block design with three blocks, each consisting of three rows of trees for each of cultivars. There were five trees in each row. Each experimental plot contained fifteen trees with the three rows. Data were collected from the three central trees in the middle rows, using the remaining trees as guards.

Cultural practices

The orchard was irrigated with drip irrigation each year from May to mid-October. The trees were watered three times a week for 5 hours each time in 2007 (1st leaf). In subsequent years the schedule was changed to daily for about 3 hours in order to accommodate the fast draining soil. Total water applied was about 800 L in 2007, and 1400-1450 L per emitter annually during 2008-2010. All trees were fertigated with 30 g of 20-20-20 N-P-K per tree per year from irrigation start up, followed by 15-0-0 at 75 g.m⁻¹ of row. All fertigations were completed by August 20 in each year. To control apple scab (caused by *Venturia inaequalis*), a fungicide (Flint 15 g/100 L) was applied before bloom, at pink tip and at petal-fall. Foliar urea was applied at a rated 3.5 kg.ha⁻¹ (1% w/v) after harvest. Fruits were hand-thinned after June drop to a spacing 15 cm. Black textile mulches were used for weed control in the tree rows.

Measurements and statistical analysis

Trunk cross-sectional area (TCA) (cm²). Trunk diameter was measured from both sides (north-south) 15 cm above the grafting section with calipers (Model No; CD-6CSX, Mitutoyo, Japan) in November of the years 2008, 2009 and 2010. Average of two measurements were taken to get trunk diameter (R) and “Area= πr^2 ” formula was used to calculate the trunk cross-sectional area.

Canopy volume (m³). Canopy widths were measured from both sides in November of the years 2008, 2009 and 2010 and canopy heights were measured from the first main branch. Then the canopy volume was calculated by using the formula of ($V = \pi r^2 h / 2$)

Tree heights (cm) and yield. Tree heights were measured as the canopy heights from the earth level. Tree high was given only for 2010. Some trees flowered in the first year after planting (2007), but the trees were not allowed to fruit, thus yield values were not calculated for 2007. Yields from each tree were weighed in each year (2008, 2009 and 2010) to find out the yield per

tree and these values were then summed to find out the cumulative yields (kg.tree^{-1}). Yield per tree was multiplied by the number of tree per hectare to find out the yield per hectare (t.ha^{-1}) and these values were then summed to find out total yield per hectare (t.ha^{-1}).

Yield efficiency (the yield per unit trunk cross-section) (kg.cm^{-2}). The yield efficiency (yield/TCA) was calculated as the ratio of yield per tree of the years 2008, 2009 and 2010 to trunk cross-sectional areas and cumulative yield efficiency of the year 2010 was calculated as the ratio of cumulative yield to trunk cross-sectional area of the year 2010 (cumulative yield/TCA in 2010).

Average fruit weight (g) and diameter (mm). A total of 10 fruits were sampled from each tree and weighed with a balance (± 0.01 g) (Radvag PS 4500/C/1, Poland). The samples were also measured for widths (mm) and lengths (mm) with a caliper and average was taken. Calculations for average fruit mass and crop load (number of fruit/ cm^2 TCA) were made using the total number of fruit per tree, not samples.

Statistical analyses were done with the SAS software package (SAS Institute, Cary N.C.). TCA, canopy volume and yield data were analyzed by analysis of variance and the means were separated by using Duncan's multiple range test. To adjust for the effect of crop load (expressed as fruit number. cm^{-2} TCA; Robinson *et al.*, 1991) on fruit characteristics, crop load was included as a quantitative source of variation in the analysis of variance for fruit characteristics. Means separation was carried out using the least significant difference (LSD) test.

Results and Discussion

In 2008 the TCA values of the trees were similar in all three cultivars. In subsequent years, Cooper 39 trees had higher TCA value than Muscat trees. Topaz trees had a TCA value between TCA of Misket and Cooper 39 apple. Canopy volume was higher in Topaz trees than Cooper 39 and Muscat apple trees in all three years. In 2010, Cooper 39 trees were significantly higher than Muscat and Topaz trees. Although Topaz trees had the lowest tree height, they had the greatest canopy volume among three apple cultivars (Table 1). The findings obtained from this study support the studies reporting that the features of the cultivars had an effect on the canopy structure (Barritt, 1987; Robinson *et al.*, 1991; Barritt, 1998; Buler *et al.*, 2001; Hampson *et al.*, 2002b; Barritt *et al.*, 2008; Özkan *et al.*, 2009; Özkan *et al.*, 2011; Küçüker *et al.*, 2014).

Table 1. Mean trunk cross-sectional area and tree canopy volume for different apple cultivars in super spindle training systems. Means in the same column followed by the same letter are not significant different according to Duncan's multiple range test ($P>0.05$)

Cultivars	TCA (cm^2)			Canopy volume (m^3)			Tree high (cm)
	2008	2009	2010	2008	2009	2010	
Cooper 39	2.19a	4.58a	5.66a	0.16b	0.23b	0.30b	273.17a
Topaz	1.71a	3.94ab	5.05ab	0.30a	0.39a	0.40a	199.17b
Misket	2.10a	3.32b	4.04b	0.23b	0.27b	0.29b	219.55b

Table 2. Yield per tree and yield efficiency for different apple cultivars in super spindle training systems. Means in the same column followed by the same letter are not significant different according to Duncan's multiple range test ($P>0.05$)

Cultivars	Yield (kg.tree^{-1})			Cumulative Yield (kg.tree^{-1})	YE (kg.cm^{-2})			CYE (kg.cm^{-2})
	2008	2009	2010		2008	2009	2010	
Cooper 39	2.18a	3.49a	8.63a	14.29a	1.08a	0.78a	1.52a	2.13a
Topaz	0.98c	2.27c	3.71c	6.96c	0.60a	0.58b	0.74b	1.33b
Misket	1.23b	3.04b	5.75b	10.02b	0.59a	0.91a	1.43a	1.86ab

Along the experiment period, the yield values indicated significant differences between cultivars. The highest yield per tree was obtained from Cooper 39 cultivar in all three years, and this was followed by Muscat and Topaz cultivars. When the cumulative yield values were examined for three years, the difference between cultivars was found statistically significant. The highest cumulative yield (14.29 kg /tree) was determined in Cooper 39 cultivar (Table 2).

The simplest way to express yield versus tree size is to determine the yield efficiency (yield per trunk cross-sectional area) (Westwood, 1995). In this study, yield efficiency (YE) did not differ significantly among cultivars in 2008. In the subsequent years, Topaz cultivars had lower YE value than the other two cultivars (Table 2). Actually, Palmer *et al.* (1992) stated that the cultivar did not have an effect on yield per tree in the early years; however, this effect showed itself clearly in the following years. Many researchers reported that the differences between cultivars regarding yield per tree and yield efficiency are less in cases where tree density and rootstocks are the same under the same training system (Barritt, 1989; Callesen, 1993; Barritt 1998; Barritt, 2000; Wertheim *et al.*, 2001). Contrary to above findings, in this study, significant differences were determined among cultivar in terms of yield, although rootstock, density and training system were the same. Three-year cumulative yield of Cooper 39 was two-fold higher than that of Topaz. Cumulative yield efficiency determined in 2010 was higher in Cooper 39 compared to two other cultivars. Thusly, Özkan *et al.* (2009) investigated the effects of super spindle on different apple cultivars and found that the cultivar Cooper 39 had higher yields than the other cultivars. Similarly, Küçük *et al.* (2011; 2014) investigated the effects of training systems on different apple cultivars, Engin and Özkan (2011) on different pear cultivars and reported that cultivars had significant effects on yields of the same planting spacings and training systems.

Table 3 presents the yield per hectare of cultivars trained to super spindle training system. While there was no difference between cultivars in the first year (2008), in the subsequent years significant differences were determined between the cultivars. The highest yield per hectare was determined in Cooper 39 and this was followed by Muscat and Topaz cultivars. When the cumulative yield per hectare was examined, Cooper 39 was determined to have the highest value (142.93 t.ha⁻¹) (Table 3). There was no difference between the cultivars with respect to fruit diameter and fruit mass values in 2008 and 2009, whereas in the last year of the experiment, Cooper 39 had lower fruit mass and fruit diameter values compared to Topaz and Muscat apples. Fruit mass and fruit diameter values of Topaz and Muscat apples are similar in 2010 (Table 4).

Table 3. Yield per hectare efficiency for different apple cultivars in super spindle training systems. Means in the same column followed by the same letter are not significant different according to Duncan's multiple range test (P>0.05)

Cultivars	Yield (t.ha ⁻¹)			Cumulative Yield (t.ha ⁻¹)
	2008	2009	2010	
Cooper 39	21.80a	34.87a	86.27a	142.93a
Topaz	9.80a	22.70c	37.13c	69.63 c
Misket	12.30a	30.40b	57.53b	100.23b

Table 4. Least-squares means for average fruit diameter and fruit mass (adjusted for crop load) efficiency for different apple cultivars in super spindle training systems. Means in the same column followed by the same letter are not significant different according to Duncan's multiple range test (P>0.05)

Cultivars	Fruit diameter (mm)			Fruit mass (g)		
	2008	2009	2010	2008	2009	2010
Cooper 39	68.20a	64.31a	58.24b	174.57a	171.33a	102.50b
Topaz	65.32a	65.67a	66.62a	148.17a	156.93a	144.25a
Misket	65.45a	68.25a	64.44ab	174.09a	161.67a	151.73a

Conclusions

Considering the advantages provided in yield, quality and labor, the present study revealed that Super Spindle system, commonly used in countries with developed fruit culture and available for dense plantation, could reliably be used in Turkish orchards.

Acknowledgements

This study was supported by The Scientific and Technological Research Council of Turkey (TÜBİTAK), TOVAG (Project No: 106 O 096), we greatly acknowledge the financial support.

References

- Barritt, B.H. (1987). Orchard systems research with Decidious trees: a. brief introduction. *Hortscience*, 22 (4): 548-549.
- Barritt, B.H (1989). Influence of orchard system on canopy development, light interception and production of third year Granny Smith apple trees. *Acta Horticulturae*, 243:121-130
- Barritt, B.H. (1992). Intensive orchard management. *Good Fruit Grower*, 1005 Tieton Drive, Yakima, Washington.
- Barritt, B.H. (1998). Orchard management systems for fuji apples. *Compact Fruit Tree*, 31(1): 10-12.
- Barritt, B.H. (2000). The hytec (hybrid tree cone) orchard system for apples. *Acta Horticulturae*, 513: 303-309.
- Barritt, B.H., Konishi, B. and Dilley, M. (2008). Performance of four high density apple orchard systems with Fuji and Braeburn. *Acta Horticulturae*, 7772: 389-394
- Buler, Z, Mika, A., Treder, W. and Chlebowska, D. (2001). Influence of new training systems of dwarf and semidwarf apple trees on yield, its quality and canopy illumination. *Acta Horticulturae*, 557: 253-259.
- Baughar, T.A., Suman-Singha, Leach, D.W. and Walter, S.P. (1994). Growth, productivity, spur quality, light transmission and net photosynthesis of 'Golden Delicious' apple trees on four rootstocks in three training systems. *Fruit Varieties Journal*, 48(4): 251- 255.
- Callesen, O. (1993). Influence of apple tree height on yield and fruit quality. *Acta Horticulturae*, 349: 111-115
- Dumanoglu, H., Erdoğan, V., Aygün, A. and Javadisaber, J. (2009). Effect of extreme climate conditions in summer on fruit quality of 'Granny Smith' apple in Ankara. *Research Journal of Agricultural Sciences*, 2(2): 193-199.
- Engin, K. and Özkan, Y. (2011). Effect of different training systems on vegetative growth of Santa Maria and Deveci, pear varieties grafted on OHF 333 and quince a rootstocks Turkey VI.Ulusal Horticulture Congress, 04-08 October 2011, Şanlıurfa.
- Hampson, C., Quamme, H.A. and Brownlee, R. 2002a. Canopy growth, yield and fruit quality of Royal Gala apple trees grown for eight years in five tree training systems. *Hortsciences*, 37: 627-631.
- Hampson, C., Quamme, H. and Brownlee, R. (2002b). Tree density or training system-what is important in apple orchard design?. *Compact Fruit Tree*, 35(2): 48-50.
- Hampson, C., Quamme, H.A., Kappel, F. and Brownlee, R.T. (2004). Varying density with constant rectangularity: II. Effects on apple tree yield, fruit size and fruit color development in three training systems over ten years. *Hortscience*, 39 (3): 50-51
- Heinicke, D.R. (1975). High density apple orchard planting, training and pruning. *USDA Agricultural Handbook*, 458 pp.
- Küçük, Y., Özkan, K. and Yıldız, K. (2011). Determination of early period performance of hytec and vertical axis training systems in different apple cultivar budded M9 rootstock Turkey VI.Ulusal Horticulture Congress, 04-08 October 2011, Şanlıurfa.

- Kucuker, E. and Ozkan, Y. (2014). Early performance of slender spindle and vertical axis training systems in apples. *Anadolu Journal of Agricultural Sciences*, 29(2):100-105
- Marini, R.P. and Barden, J.A. (2004). Yield, fruit size, red color, and a partial economic analysis for 'Delicious' and 'Empire' in the NC-140 1994 Systems Trial in Virginia. *Journal of The American Pomological Society*, 58(1): 4-11.
- Özkan, Y. (2008). The high density planting in Turkey. *The Yield With Gübretaş*, 15: 15-16.
- Özkan, Y., Küçüker, E., Özdi, S., Engin, K., Mehter, B. and Alpaslan, B. (2009). Tree and fruit characteristics in Amasya Misketi, Topaz and Cooper 42 varieties Budded/Grafted on M 27 practiced super spindle training. *Research Journal of Agricultural Sciences*, 2(2): 145-151.
- Özkan, Y., Akça, Y., Yıldız, Y., Çekiç, Ç., Özgen, M., Küçüker, E. and Yaman, F. (2011). Analysis of modern training systems in Dwarfed Apple growth Turkey VI. *Ulusal Horticulture Congress*, 04-08 October 2011, Şanlıurfa.
- Palmer, J.W., Avery, D.J. and Wertheim, S.J. (1992). Effect of apple tree spacing and summer pruning on leaf area distribution and light interception. *Scientia Horticulturae*, 52: 303-312.
- Robinson, T.L., Lakso, A.N. and Carpenter, S.G. (1991). Canopy development, yield, and fruit quality of 'empire' and 'delicious' apple trees grown in four orchard production systems for ten years. *Journal of The American Society for Horticultural Science*, 116:179-187.
- Weber, M.S. (2001). Optimizing the tree density in Apple Orchards on Dwarf rootstocks. *Acta Horticulturae*, 557: 229-234.
- Wertheim, S.J., Wagenmakers, P.S., Bootsma, J.H. and Groot, M.J. (2001). Orchard systems for apple and pear: conditions for success. *Acta Horticulturae*, 557: 209-227.
- Westwood, M.N. (1995). *Temperate-zone pomology physiology and culture*, Third edition. Timber Press, Portland, Oregon.